NIGHT-TEMPERATURE STUDIES IN THE ROSWELL FRUIT DISTRICT.

By Cleve Hallenbeck, Observer.

[Dated: Weather Bureau Office, Roswell, N. Mex., July 23, 1918.]

The region covered by this discussion embraces an irregular area of some 1,200 square miles lying almost entirely west of the Pecos River. Its length, north and south, is about five time its average width, with Roswell within 5 miles of its northern limit, and Carlsbad at its southern limit. (See fig. 1.) This area includes practically all of the fruit-growing and farming districts of the Pecos Valley.

In this region, which is represented by the Roswell Weather Bureau station and six substations, departures of the temperature, on clear nights, from a normal radiational curve are due to five controls or influences:

1. The importation of warmer or colder air.
2. Topographical influences.
3. Air drainage.
4. Mixture of the lower air with the air of higher levels.
5. Local inequalities in the heating and cooling of the ground and lower air.

The dewpoint or humidity factor is omitted, since it is a factor that may be ignored in this district.

When none of these influences is appreciable, which is not often, the night temperature curve is very nearly normal. The term "normal curve," as used herein, refers to a night temperature trace due only to radiational cooling. It is apparent that this may vary on different nights, or in different localities. A normal cloudy night radiational curve would, in this district, have less than half the range of a clear-night curve; the range of temperature over cultivated and irrigated country likewise would be less than over the dry, bare prairie, although in each case the thermograph trace may be approximately a normal radiational curve.

The term "normal position," also used herein with reference to night temperatures, requires definition. The normal position of the temperature at any hour of any night is the point at which that hour line on the thermogram is intersected by the normal temperature curve for that night, which itself can be constructed from the completed trace by eliminating from the trace all controls other than radiation. It can also be approximately de-

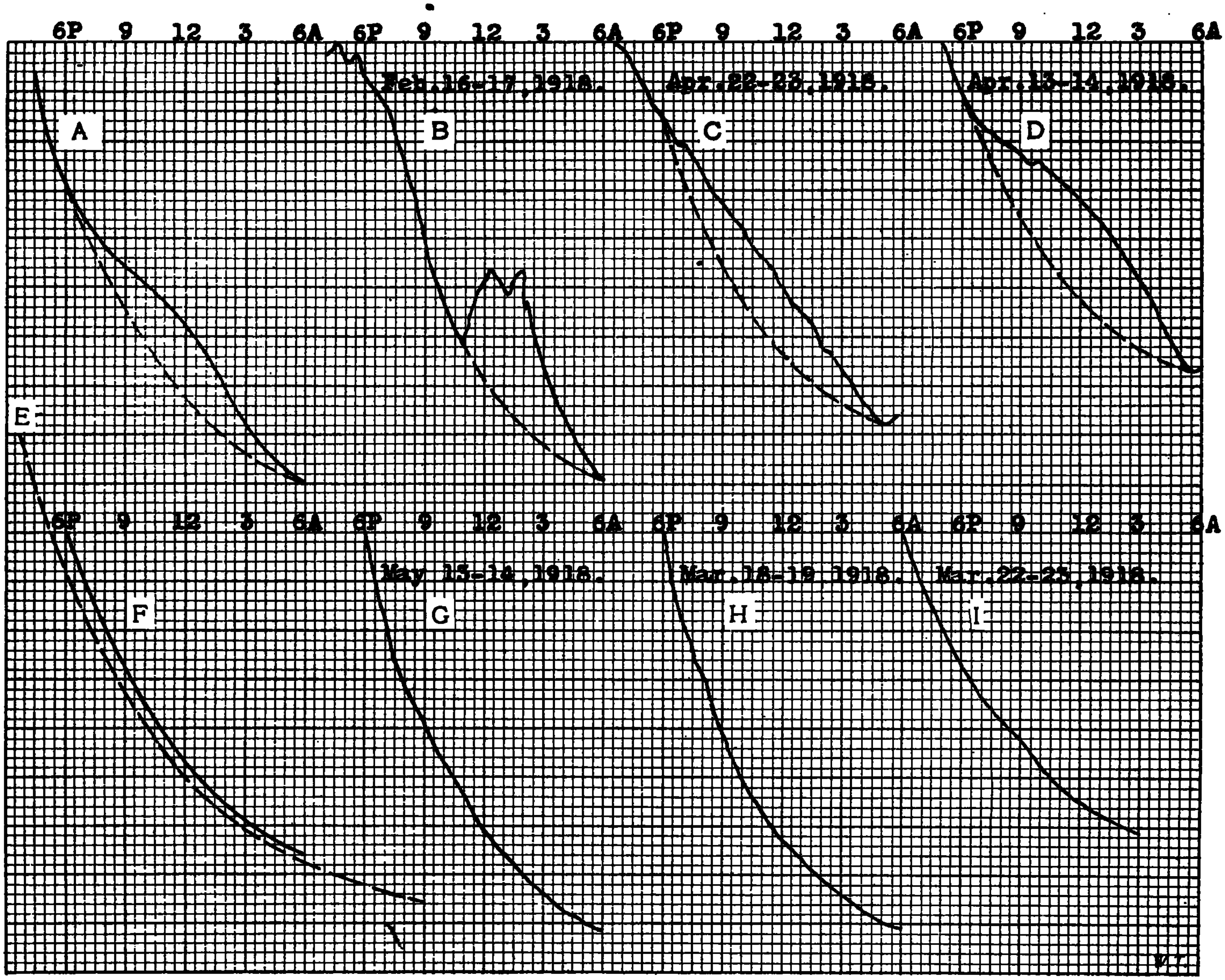

Fig. 2. A, average radiational night trace for spring of 1918. B, C, and D, individual night traces. E, a parabolic curve. F, average of all normal night traces for spring of 1918. G, H, and I, individual approximately normal night traces.

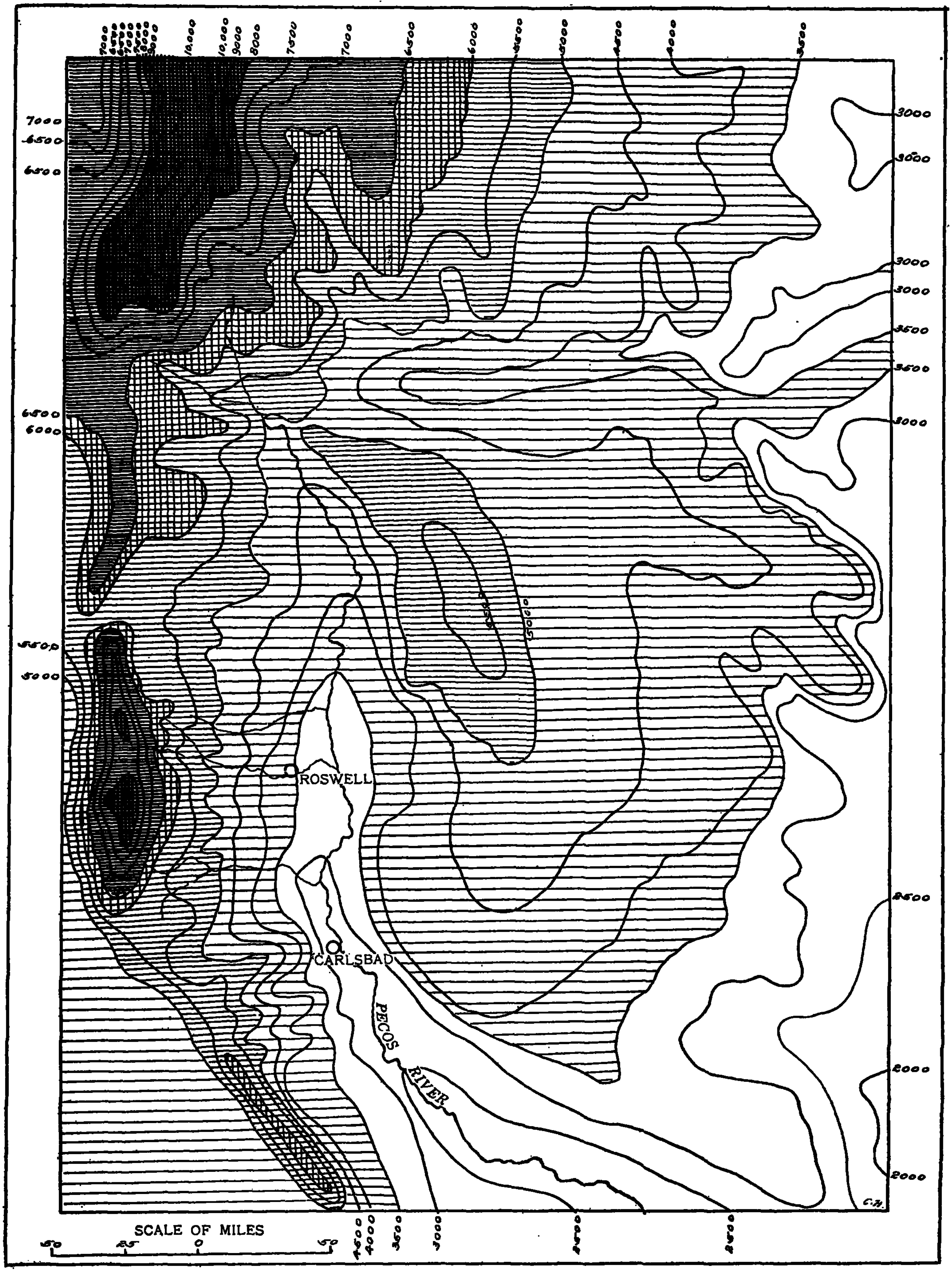

Fig. 1. Topographical map of Pecos Valley in New Mexico. Contours drawn for every 500 feet vertical elevation up to 8,000 feet, and for every 1,000 feet from 8,000 to 10,000.

termined early in the night, when only a portion of the trace is available, in the same way.

The temperature trace is not often even approximately normal on nights favorable to radiational cooling. The usual clear-night thermogram shows an irregular upward "bulge," generally between 9 p. m. and 3 a. m., although occasionally the greater portion of the night trace is convex upward. This characteristic of the night temperature, which occurred in this district on 59 of 95 consecutive nights during the spring of 1918, is illustrated by the four upper traces of figure 2. Trace A is the mean or composite of all "radiation" night traces from March 15 to April 30, 1918. B, C, and D are selected individual traces which, although quite different when compared with each other, all exhibit this departure above the normal path (normal paths shown, approximately, by broken curves). Traces similar to B are of

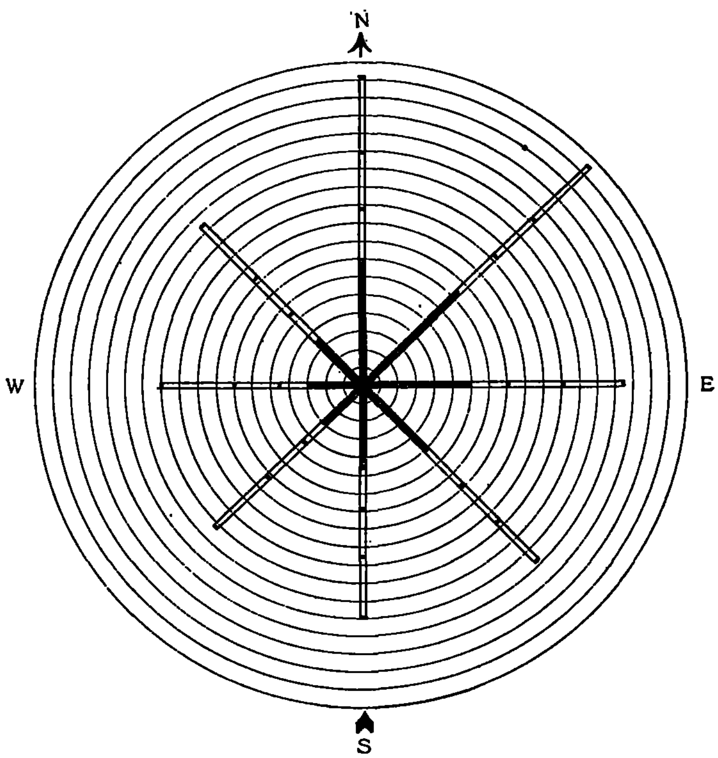

FIG. 3. Average temperature range from 6 p. m. to 6 a. m. on clear nights in spring with winds from the different directions. Solid black indicates average fall from midnight to 6 a. m., white, divided into two-hour intervals, average fall from 6 p. m. to midnight.

most frequent occurrence, although the rise (or retarded fall) usually begins earlier in the night than shown here. Trace C is a case, which is not of infrequent occurrence, where the retarded fall, and the following accelerated fall (as compared with normal curve) are such as to produce an almost uniform fall throughout the night. Every possible gradation between these selected traces, and between these and a normal radiational trace, can be found.

The lower traces of figure 2 illustrate normal traces, F being the composite of all approximately normal traces occurring during the spring of 1918, while G, H, and I are individual traces. It will be noted that F conforms almost exactly to the parabolic curve, E, and it is an interesting fact, although possibly accidental, that all the approximately normal traces during the season (10 in all), regardless of range, closely conform to some portion of the curve E.

Since an approximately normal temperature curve occurs on an average on but one night in ten, while fully five nights in ten are good "radiation" nights, it is evident that one or more of the disturbing factors mentioned are usually to be expected.

1. *Importation of warmer or colder air.*—This refers to the inflow of cold or warm air in anticyclonic and cyclonic circulations, and will not be further discussed except as such importation is modified by the topography.

2. *Topographical influences.*—Reference to figure 1 will show that, in general, winds in this district trend upward if they have an easterly component, and downward if they have a westerly component. Easterly winds, therefore, are more or less dynamically cooled, and westerly winds similarly warmed. The coldest winds are from the northeast, trending slightly upward in addition to coming from a cooler region, while southwest winds are the warmest, since they come from a warmer region and in addition trend downward.

Figure 3 illustrates graphically the wind-temperature effect of the topography for each of the 8 principal directions.

Each "ray" indicates for the spring season the average temperature range from 6 p. m. to 6 a. m. with winds from the indicated direction. The white portion is the average fall from 6 p. m. to midnight, and the black portion the fall from midnight to 6 a. m. The concentric circles are drawn for two-degree intervals. It will be noted that with southwest and west winds the average fall from midnight to 6 a. m. is only two-fifths of that for northeast, and for northwest is hardly half as much. The fall of temperature by two-hour intervals up to midnight is shown on this figure. It will be seen that for the first two hours, 6 to 8 p. m., the cooling is almost exactly the same for all directions from southwest through northwest to northeast, and for the following two hours, 8 to 10 p. m., the difference is not great. This will be referred to later, and is important in view of the fact that evening temperature forecasts based upon the cooling early in the night are usually issued by 8 p. m.

Probably the most important feature of the influence of the topography occurs when a HIGH moves eastward or southeastward across the central mountain States. No material fall of temperature beyond the normal occurs until the HIGH has spread eastward across the mountains; in fact, until this is accomplished, the fall of temperature is often retarded, or actually rises. (See fig. 4). There were two such rises during the year 1916 where the peak of the rise was the maximum temperature for the day, in spite of the fact that in each case the day was clear, the rises occurring between midnight and 6 a. m. As soon, however, as the pressure has risen east of the mountains, the wind at Roswell shifts from westerly to northeasterly, with rapidly falling temperature. This occurs before the crest of the HIGH has crossed the mountains, and frequently, after a few hours of northeast wind, there is a return to northwest or west. This return shift often gives the impression, when the twice-daily weather maps only are consulted, that the cold is imported from the west or northwest. The same shift of wind from westerly to northeasterly may occur following the passage of a LOW across the southern States of the West with a HIGH advancing southeastward *east* of the mountains, and it is in nearly every case an abrupt shift.

The three upper traces of figure 5 show the effect of this wind shift on the temperature. The broken lines represent the rise in pressure, each vertical space being equal to .0.02 inch on the mercurial barometer. The three lower traces were made with similar rises in pressure, but with the wind remaining westerly or northwesterly throughout the night. It may be of interest to note that trace F, made on the second night after trace C, reached a minimum of only 49°, while the minimum of trace C was 11 degrees lower, or 38°. The wind direction attending trace C (at top of figure) shows the return of the wind to westerly after having blown from the northeast for five hours. The wind was southwest at 6 p. m., and west at 6 a. m.; therefore it would appear from the weather maps that the unusual fall of 43 degrees had occurred with a westerly wind.

These are cases of importation of cold air controlled or modified by the topography. Such cases as those shown by traces A, B, and C, figure 5, occur, on an average, nights in spring, usually shifts to northerly or northeasterly at some time between midnight and sunrise, and in 91 per cent of the instances it has a westerly component for 2 or 3 hours before the change to northeasterly occurs. This results in a retardation of the night cooling during those hours, especially when the wind is moderate to brisk. The northeasterly wind, which is always light except when supported by a HIGH to the north, is apparently a case of air drainage and is characteristic of clear nights in spring and fall. This current, which occurs in all parts of this district and probably to some distance beyond in each direction, is probably never of considerable depth. Low stratus clouds have many times been observed moving in an opposite direction, and several early morning observations of smoke indicated a depth, at Roswell, of between 220 and 250 feet.

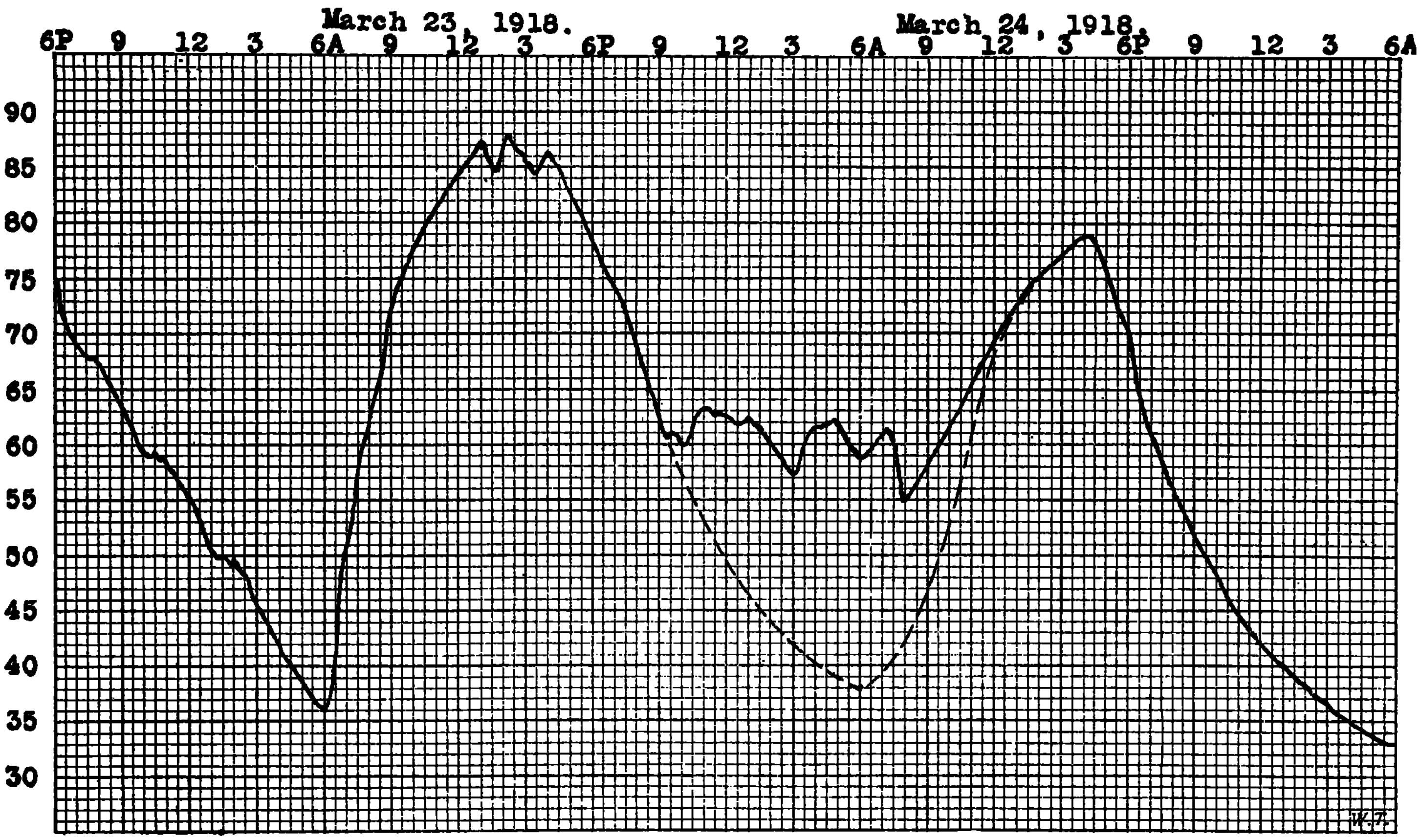

FIG. 4. Effect of continuing westerly wind in preventing the normal radiational cooling on night of March 23-24, 1918. Broken line shows curve as calculated the evening before.

twice during the critical season in spring, and as a result damaging temperatures occur on an average once each season.

3. *Air drainage.*—In the absence of controls other than radiation and solar heating, the wind at Roswell evidently would shift from south through west to north during the first half of the night, and back to south through east during the forenoon. A comparatively slight barometric gradient will modify the normal shift, which in an ideal form is not frequently observed. The tendency, however, is clearly revealed in the hourly frequency of the wind from the different directions over a period of a month or more. The maximum frequency of the wind from the different directions is as follows: North, 3–4 a. m.; northeast, 6–7 a. m.; east, 7–8 a. m.; southeast, 12–1 p. m.; south, 2–3 p. m.; southwest, 9–11 p. m.; west, 11–12 p. m.; northwest, 2–3 a. m. Even when the entire circuit is not made, the wind, on clear

An objection to the postulation of air drainage may appear in the fact that the trend of the Pecos Valley through this district is north and south, while this wind is more northeasterly than northerly. However, the Pecos Valley in New Mexico is such as to encourage the development of night air drainage.[1] Its southward slope is about 10 to 12 feet per mile, and the grade is quite uniform. The west and east slopes have each a horizontal width of some 60 miles; eastward, however, the maximum elevation is only about 1,500 feet above the elevation of Roswell, while westward, in an equal horizontal distance, the land rises 4,000 to 5,000 feet above the elevation of this station. The valley floor contains no elevations or depressions worthy of mention.

[1] "Air drainage" is here used in the sense of a slow, steady flow down a gentle slope, where the cooling of the air by conduction and by radiation is sufficient to offset the adiabatic heating of the air in its slow descent. There is no question but that air drainage as usually thought of, i. e., a continuous flow of air down a slope, can occur under such conditions. See Bulletin of the Mount Weather Observatory, vol. 6, pp. 123-124.—W. R. G.

The tributaries of the Pecos are insignificant and follow shallow depressions; in some cases the streams have no valleys at all, being nothing more than arroyos. Some idea of the smoothness of the valley floor may be gained from the fact that the orchards and masses of shade trees in this district offer greater obstruction to the flow of air than do any features of the valley landscape.

It will be noted that Roswell is located some 8 miles west of the Pecos River (see fig. 1), and where the maximum slope of the land is to the southeast; so that a northeasterly wind is blowing nearly at right angles to the direction of greatest slope.

Since the wind prior to the shift to northeasterly nearly always has a westerly component, the fall of temperature is retarded before the shift, with an accelerated fall after. It is possible that this is not entirely a topographic influence, since the same condition often obtains with a steady wind from some one direction. The writer has never noted a case of retarded fall with north, northeast, or east winds, or of an accelerated fall with west winds.

In figure 6 are four sets of thermograph traces illustrating the effect of air drainage. The first set (A to D) shows the temperature fall resulting from shifts to northeast at (A) 2 a. m., (B) 3 a. m., (C) 4 a. m., and (D) 5 a. m. Trace D also shows the effect of a late shift in advancing the time of minimum temperature, which is further illustrated by traces E to H. On the first three of these four dates (E to H) the minimum occurred one and a half hours after sunrise, and on the fourth the minimum was not reached until about three hours after sunrise. Clear skies prevailed on each of the four mornings. On the first three the observer would have been justified in assuming at sunrise that the minimum had been reached, since the temperature in each case was rising at the time. On the fourth date the minimum apparently was reached at 6 a. m., and for an hour thereafter the temperature rose. The sun was then 1 hour 45 minutes high, and the following unexpected fall of temperature, amounting to 10 degrees, could have been due only to an influx of cold air. This fall attended a shift of the wind from northwest to northeast.

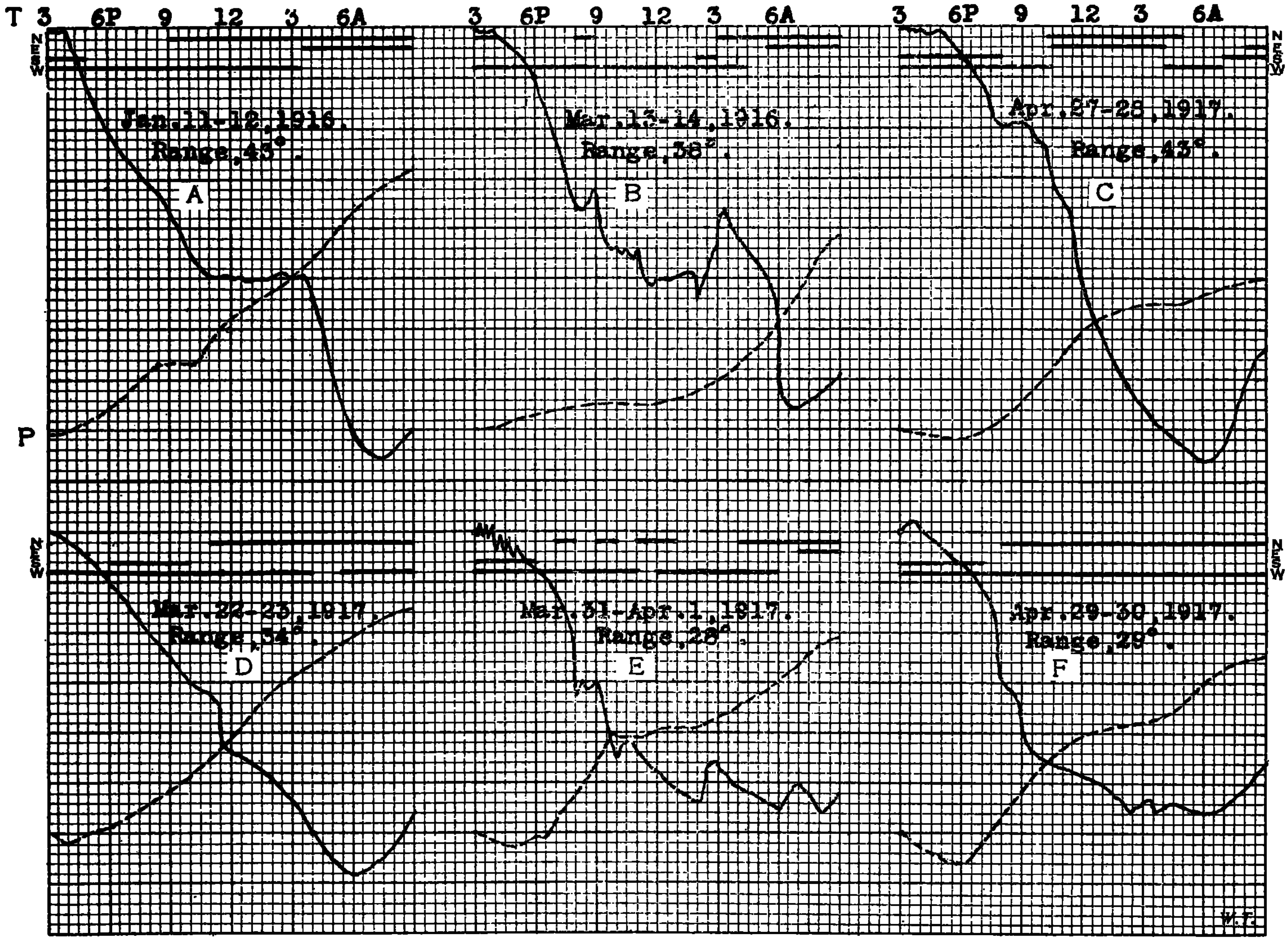

FIG. 5. Modification of importation of cold air, by topography. Upper traces: Temperature fall attending shift of wind from westerly to northeast with rising pressure. Wind direction at top of trace; broken line represents pressure rise. Lower traces: Similar pressure rises, with wind remaining westerly.

Traces I to L, inclusive, are examples of what local orchardists call the "dip" in the temperature, and are really sharp falls due to late shifts of the wind to northeasterly, occurring usually after daybreak and sometimes after sunrise. These sharp and unexpected falls are one of the chief concerns of the fruit growers in this district. Several orchardists, according to their own information, have suffered serious loss in past seasons from morning "dips" that, occurring after the minimum was believed to have been reached, took them unawares and damaged the fruit before additional heaters could be brought into action.

On an average, five such "dips" occur each spring (Mar. 15 to Apr. 30), two of which reach injurious temperatures. Injurious temperatures occurring half an hour or more after sunrise (clear weather dates only being considered) occur, on an average, twice each spring.

It is the practice of a number of experienced orchardists to hold their orchard temperatures several degrees above the critical point, so as to minimize the injurious effect of any sudden or unexpected inflow of cold air. The wind is usually very light at the time, and the change in direction, occurring without any change in velocity, may often pass unnoticed.

It should be stated here that the sharp falls such as have been discussed occur only with shifts of the wind to northeasterly; that is, to any direction between north and east. Accelerated falls may attend winds from other directions, but nothing of the nature of a sudden fall.

Traces M to P of figure 6 illustrate the effect of continued westerly winds during the night. Up to midnight these traces are not noticeably different from those with morning-air drainage, since up to midnight the wind in each case is westerly or with a west component.

Some idea of the frequency of air drainage may be obtained from the following: In March, 1918, there were 15 "radiation" nights, on 14 of which air drainage occurred. In April there were 15 radiation nights, 11 of which had a period of air drainage. In May, with 13 radiation nights, air drainage occurred on 6. It will be noted that the relative frequency of this condition decreases as the season advances.

4. *Mixing of air strata of different temperatures.*—Spring being normally the driest season of the year in this district, the daily range of temperature also is normally greatest during this season. In country exposures nights with 40 to 50 degrees radiational cooling are the rule, and the temperature frequently falls as much as 30 degrees between sunset and midnight. Outside the farming dis-

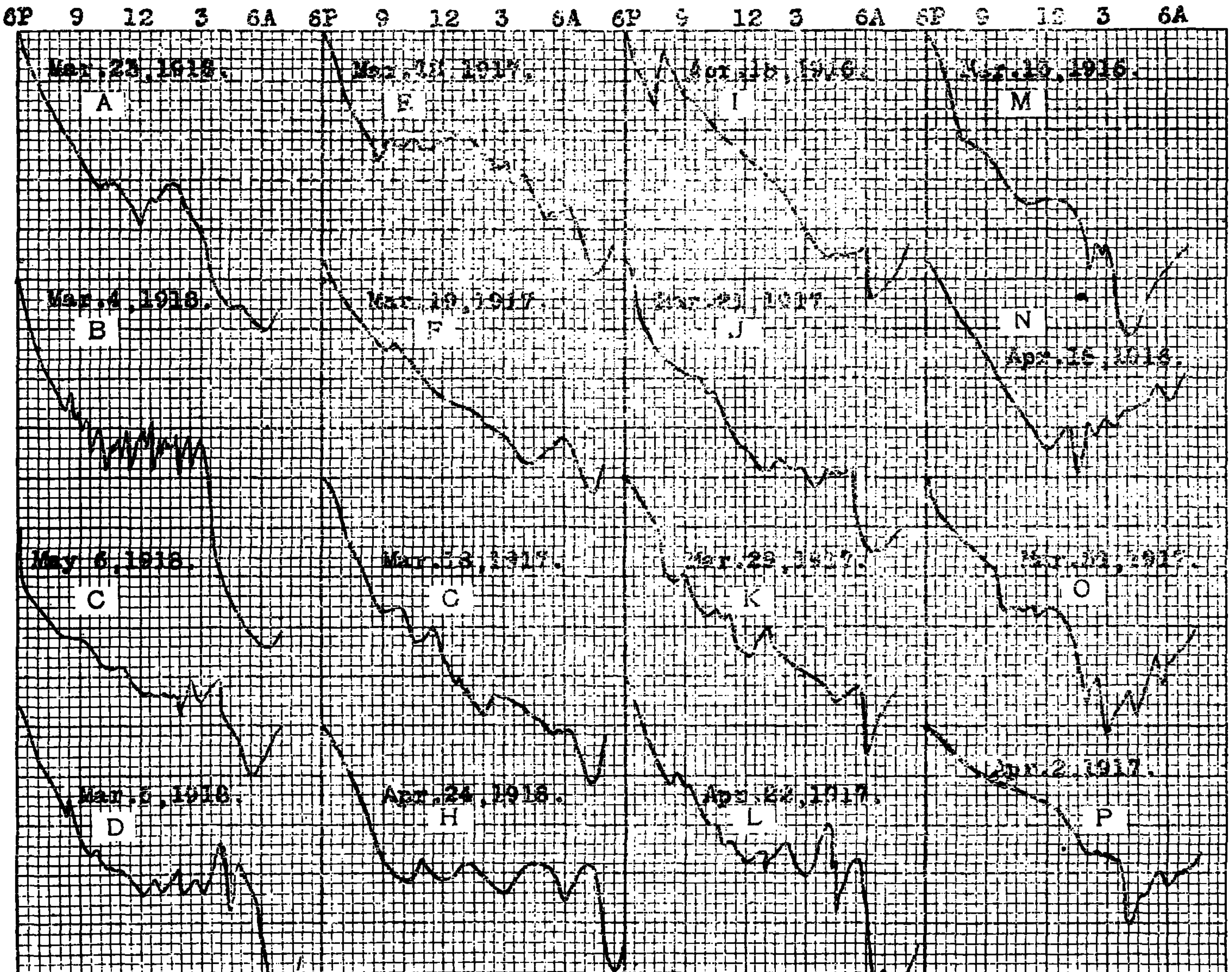

Fig. 6. A to D: Temperature falls due to air drainage. E to H: Illustrating effect of late air drainage in advancing time of minimum temperature. I to L: Sharp falls in temperature, occurring after daylight (I and L, after sunrise), due to late shifts of the wind to northeast. M to P: Effect of continued westerly winds through the night.

tricts the range of temperature must be still greater. This rapid cooling during the night, following the equally great heating during the day, is very favorable to the establishment of pronounced vertical temperature inversions, and the mixing of the cool lower stratum with the air of higher levels would result in temperature fluctuations of considerable amplitude. Such disturbances of the temperature would be expected to occur with a change in the wind direction or with an increase in the velocity, and it is attending such changes that the temperature fluctuations

The relative amounts of heating and cooling must be quite different for the different areas. The writer has often noticed the change in temperature experienced in passing from a region of arid prairie land to an irrigated region covered with growing crops. The writer also once experienced, while traveling along a level country road in the early morning, three distinct alternations of warm and cool air; the difference in temperature was not only noticeable but remarkable, probably amounting to as much as 10 degrees.

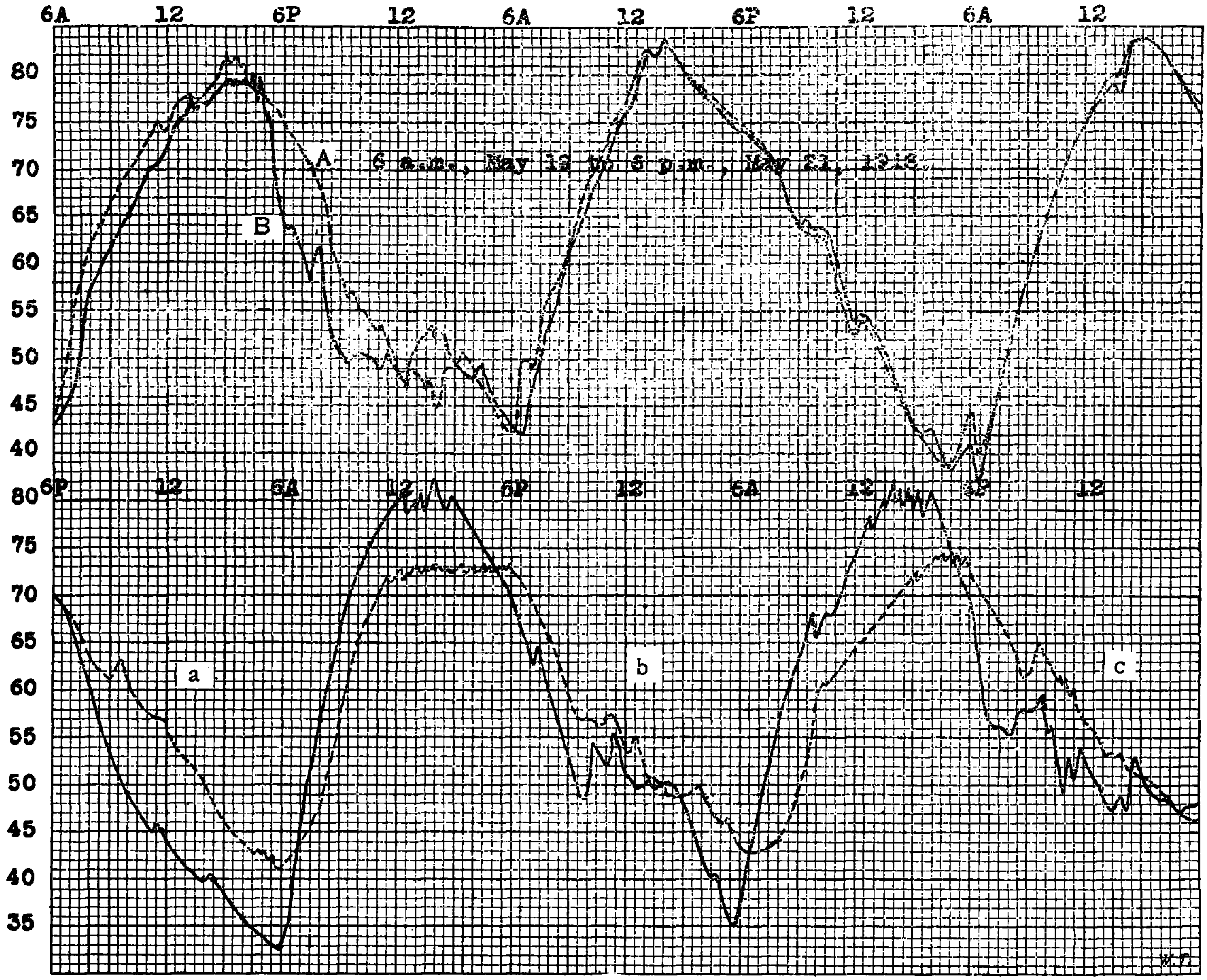

FIG. 7. Upper traces: Effect of local inequalities in night cooling (night of May 19-20). Lower traces: Comparison of rural temperatures (solid line) with city temperatures (broken line), and showing (*a*) a night with approximately normal cooling, (*b*) a night with air drainage after 2 a. m., and (*c*) a night with retarded cooling after 7 p. m.

most commonly occur. They also are more frequent and of greater amplitude after midnight than before, and during periods of dry weather than when the ground is moist.

5. *Unequal heating of the ground and lower air stratum.*—The irrigated and cultivated portions of the Pecos Valley are not contiguous. Large areas, comprising from less than a square mile up to 40 to 50 square miles, under irrigation and cultivation and covered with vegetation often luxuriant, are interspersed with almost equal areas of dry, bare prairie land, while surrounding the whole is a vast stretch of arid or semiarid country.

Such conditions may produce temperature fluctuations both day and night, especially when the wind is variable. In the farming districts these probably are rises during the day and up to the median temperature hour and falls thereafter.

An example of what the writer believes to be temperature variations of this type is shown by the upper traces of figure 7 (May 19). The two superimposed traces were made at two substations less than 3 miles apart, whose exposures and general surroundings were as nearly alike as was practicable. As a rule the thermograph traces of these two stations are nearly identical, as shown by the traces for the following two days (May 20 and 21). On the date in question the night traces were so dissimilar that it would appear they were made at stations far apart or under widely different conditions of exposure.

The lower traces of figure 7 are a comparison between thermograph records made at the Weather Bureau station, under city influences (broken line), and at the substation at the writer's residence, under entirely rural surroundings (solid line). Besides showing the effect of city influences, these show the differences between the two records on (*a*) a normal radiation night, (*b*) a night with air drainage, and (*c*) a night with retarded cooling after 7 p. m.

It has been mentioned that the retarded cooling during the first half of the night, followed by an accelerated fall of temperature, is often observed with other conditions of wind direction than westerly wind shifting to northeasterly. This may have a possible explanation in the fact that the range of temperature in the farming region must be less than the range over the bare prairie. The daytime heating and the night cooling would each be less in the cultivated and irrigated region. Winds from off the prairie would, therefore, tend to retard the cooling until they were themselves cooled radiationally to the same temperature, after which, being cooler than the air over the farming country, they would tend to accelerate the fall of temperature. In such cases, however, the temperature evidently should begin to fall at a rate greater than normal at about 8 p. m. (the median temperature hour) instead of at midnight or after, as observed. The fact that the thermographs are located some distance from the open prairie, in the interior of the farming country, may explain this discrepancy.

The small but abrupt drop in temperature that accompanies the arrival of an early morning northeast wind is without question due to unequal cooling. This air is from off the exceptionally bare prairie land to the north and northeast, and, being cooled radiationally to a temperature several degrees below that of the farming district, naturally flows down valley through that district.

Forecasting.—It is evident from the foregoing that the wind direction is an important factor to be considered in forecasting night and minimum temperatures. On occasions it may be the only factor, in addition to the normal radiational cooling.

On nights when the wind direction will be controlled by pressure gradients, the topographic factor has to be considered. Normal falls of temperature usually occur with south and southeast winds, as the mechanical cooling about neutralizes the excess warmth.

On clear nights, the fall of temperature up to 8 or 9 p. m. is about the same for all directions of wind having a westerly or northerly component, and therefore the cooling in the early evening may be no guide as to what the subsequent fall of temperature is likely to be. Even when the pressure is rising with a northwest wind, the cooling during the early hours of the night may not be more than normal, and may even be less than normal.

This condition, where a HIGH is developing across the central mountain States, presents a situation that requires careful attention. The time at which the wind will shift from northwest to northeast often determines whether or not injurious temperatures will be reached. This may occur at any hour of the day or night, although its time of maximum frequency is about sunset, with a secondary maximum near midnight. But even if it occurs as late in the night as 3 a. m., in the spring it is likely to reduce the temperature to a critical degree by sunrise. The examples that are submitted in figure 5 are not extreme cases. The following is an example of an extreme case that came under the writer's personal observation: On October 28, 1917, a sudden shift of the wind from west to northeast resulted in a fall of temperature of 27 degrees in one hour and 45 degrees in five hours. In two hours the temperature was reduced from 68° to freezing; and since this occurred at night, a great deal of picked, exposed fruit was frozen before it could be sheltered or protected.

That such a shift will occur can usually be successfully forecast from the weather and pressure-change maps, and the time within three hours can often be forecast also. Further than this it is impossible to go. It is of some value, however, to have the fruit growers advised of the impending change, so that they can prepare in advance. Where the local conditions announce a freeze 12 to 24 hours in advance the orchardist needs no further notice; but in the case of the sudden falls of temperature here described, the fall is nearly always preceded by temperature above normal, and sometimes, as mentioned before, there is a decided rise for two to four hours preceding the shift of the wind.

On clear, still nights in spring a period of air drainage is usually to be expected; but since the retarded cooling, which normally occurs before midnight, is in most cases compensated for by the following rapid cooling, the median hour temperature method of calculating minimum temperatures can be employed with a fair degree of success. Where the cooling is noticeably retarded before the median hour, the probable range for the night can be approximated by applying a correction to the median hour temperature.

The late, sharp falls in temperature, such as are shown in figure 6, present a slightly different problem. As a rule it is impossible to forecast on the preceding day even the approximate time when the northeast wind will set in. "Dips" in the temperature, therefore, can not be forecast much in advance. Before the shift, however, the wind velocity decreases for two to four hours from an average of about 6 miles per hour to about 2 miles or less; sometimes it is almost calm for half an hour before the shift occurs. This condition enables the forecaster to give the orchardists precautionary advices an hour or more in advance. It is the writer's experience that on critical nights the observer is kept up all night, so that the issuing of a precautionary warning at 3 or 4 a. m. is no inconvenience.

At such times the fact that the normal minimum will very probably be reached is an aid to the forecaster in estimating the amount of the early morning fall of temperature. The only danger is that the normal fall may be exceeded, as sometimes is the case when late shifts of the wind occur.

Variations in the temperature, due to the mixture of air strata of different temperatures, or to inequalities in the cooling of the lower stratum, may occur early in the night, so that the temperature at the median hour may not be the true median temperature. Such variations are easier to detect from an examination of the thermograph trace than is a gradually retarded fall. In both cases it is necessary to correct the median hour temperature, or the temperature at 8 p. m. in case the cooling from 6 p. m. to 8 p. m. is used, in estimating the probable minimum.

It was stated on page 364 that the normal cooling for any night can be determined at an early hour—say at 8 p. m.—if the accidental variations occurring up to that hour can be eliminated. And since on clear, still nights the range is, with certain exceptions, very nearly the same as would have occurred with normal cooling, it follows that the actual range can be very nearly calculated.

The writer takes into account the following in eliminating the accidental variations from the thermograph trace when such occur before 8 p. m.: (1) The character of the trace before the irregular variations began; (2) observations of the wind direction for two hours or more before 8 p. m.; (3) the range of temperature on previous similar nights; (4) the character of the temperature variations.

If the night promises to be favorable to radiational cooling, then the range of temperature on previous similar nights is of value. Minimum temperatures calculated by this means alone will be within 3 degrees of the actual minimum about half the time.

Frequently the normal cooling up to the hour of observation (8 p. m.) can be closely approximated by projecting the portion of the thermograph curve made before disturbing influences set in downward along a normal path; the point on this projected curve at the median hour is the normal position of the median temperature.

The character of the temperature variations is sometimes of considerable aid in plotting the normal curve. Any disturbances of the temperature at or near the hour of observation on "radiation" nights are nearly always rises. Such disturbances are often in the form of a number of rises and falls, and the lowest points reached are usually on or very close to the normal radiational path, as in trace C, figure 8.

Observations of the wind direction are also of value in determining the character of the night trace.

The three upper traces of figure 8 illustrate the method used in correcting the median hour temperature. Trace A was made at the New Mexico Military Institute, where the median temperature hour for April is 7:50 p. m., and B and C were made at the writer's residence, where the median hour for February is 7:35 p. m. The calculated normal curve for each night, up to 8:30 p. m., is shown by the broken lines. The asterisks at 6 a. m. mark the calculated minimum temperatures, while the small circles mark the minimum temperatures that would have been calculated by using the actual median hour temperature. Traces D, E, and F are examples of temperature fluctuations that did not begin until after the median temperature hour. Here the usual median hour temperature method may be applied with satisfactory results.

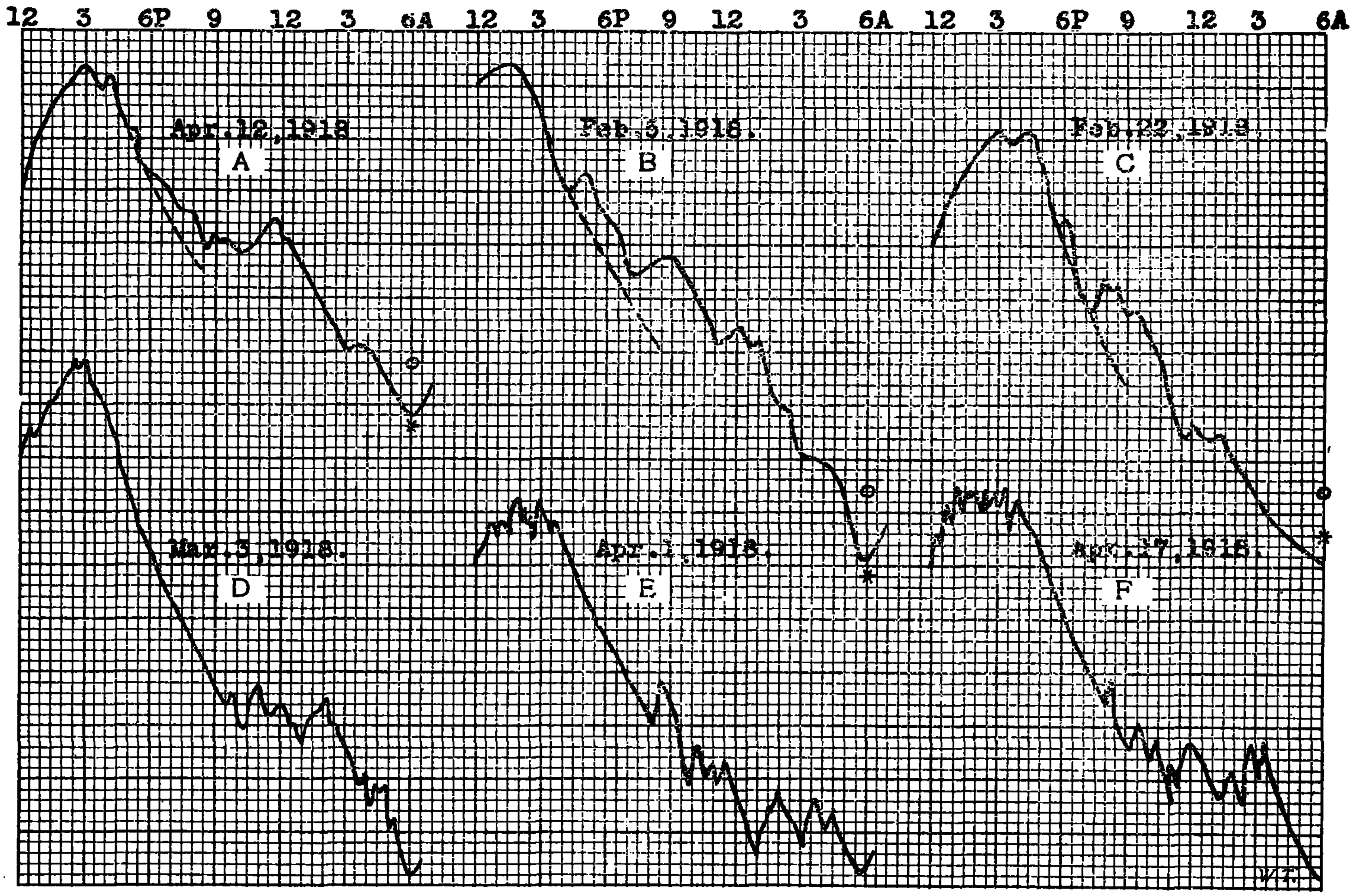

FIG. 8. Application of "corrected" median hour temperature method. On upper traces, broken line shows calculated normal curve up to 8.30 p. m. Lower traces: Cases where temperature fluctuations were not apparent at the time of median temperature.

In determining to what extent, if any, the fall of temperature early in the night is being affected by the importation of warmer or colder air, the character of the temperature curve during the day, and the time of maximum temperature, are considered. An inflow of cold air sufficient to reduce the temperature 1° per hour will cause the maximum to occur about one hour earlier than normal, provided this cooling influence has been active throughout the day. With clear weather, a slight importation of cold or warm air can also often be detected by comparing the noon temperature with the temperature at 6 p. m. The difference between these two temperatures varies with the season, but in April, in rural exposures in this district, the temperature at 6 p. m. is normally 7 degrees lower than at noon. If, for example, the temperature at 6 p. m. is 10 degrees lower than at noon, it is assumed that during the 6 hours there has been an inflow of cold air sufficient to reduce the temperature 0.5 degree per hour. Whether such cooling was active throughout the six hours can often be determined from the thermograph trace. The use of these methods presupposes that the cooling or warming will continue throughout the night, which is not always the case. Where the reception of solar radiation is materially interfered with by cloudiness during the afternoon the method has no value.

The condition of the ground as regards moisture is also a factor to be considered. A rain will materially lessen the range of temperature for the following night, and probably for several nights, depending on the amount of moisture retained by the ground. It will also reduce the irregular variations in both number and amplitude.

The dewpoint is so infrequently reached that the forecaster can usually afford to ignore it. In the spring the average difference between the minimum temperature and the morning dewpoint is 18 degrees.

It was stated in a preceding paragraph that there are exceptions to the rule that the normal minimum will be very nearly reached on nights favorable to radiational cooling. One of these exceptions is where the wind, which is normally westerly during the first half of the night, continues from the same general direction throughout the night. This is due, of course, to an increasing pressure gradient from east to west across New Mexico, but it is often difficult to know whether or not such gradient will be sufficient to control the wind direction during the second half of the night. It may develop during the night, when such development can not be foreseen on the preceding day. This is likely to modify greatly the course of the temperature after midnight, and minimum temperature forecasts on such occasions may be as much as 10 or 12 degrees in error. A single example of this is presented in figure 4, for the night of March 23–24, 1918. The broken line here represents the normal cooling, as calculated at 9 p. m. the evening before. Also, with westerly winds, the minimum temperature is likely to occur at any time between midnight and morning. In figure 6, traces M to P, the minimum of each trace was due to a temporary shift of the wind to east or northeast.

The second exception to the rule is where a late shift of the wind to northeast occurs. Traces B, D, J, K, and L, of figure 6, may serve as illustrations.

Temperature irregularities due to the mixing of the lower and upper air or to the unequal cooling of the lower air do not materially affect the minimum, except in the case where such a fluctuation occurs at the time of minimum temperature. This unequal cooling is normally most pronounced early in the morning, and the temperature variations due thereto may be considerable, but as a rule they are not of sufficient amplitude to destroy the value of the forecast.

Most of the local orchardists who practice orchard heating are equipped to meet successfully any low temperature that is likely to occur. Consequently they are as much interested in knowing at what hour of the night the temperature will reach a critical degree as in knowing what the minimum is likely to be. Owing to the usual extreme irregularity of the night thermograph trace on nights favorable to radiational cooling, it is easier to calculate the temperature for different hours of the night when there is a decided inflow of cold air. In spring, however, the temperature rarely reaches a critical point before 4 a. m., and the temperature at this hour can be calculated with a greater degree of accuracy than for any preceding hour back to midnight. This is because, as has been stated, the temperature on "radiation" nights tends to regain its normal path in the early morning hours.

ICE STORMS IN THE SOUTHERN APPALACHIANS.

Verne Rhoades, Forest Examiner in Charge Pisgah Purchase Area.

Numerous brief records have been made from time to time relating to the severity of ice storms in various sections of the United States. So far as the writer is acquainted with the accounts of such atmospheric disturbances published in this country, none of them speaks of damage to tree growth as being as widespread or so injurious in their effects as that which was occasioned by an ice storm which passed over the hardwood region of a portion of western North Carolina and northwestern South Carolina in the early spring of 1915.

A rain began falling at 6 p. m. on March 4, 1915, and about midnight the temperature dropped to freezing. The rain thereupon turned to sleet, and for the ensuing 24 hours, from midnight on the 4th to midnight on the 5th, the precipitation was practically continuous either as rain or as sleet. A heavy coating of ice encased the branches, both large and small, of all trees found within the compass of the storm, which followed a general southwesterly direction in the vicinity of Hendersonville, Saluda, and Tryon, N. C.

At the higher elevations in the mountains—in Pisgah Forest, for example—the greatest amount of damage to tree growth was on the slopes facing the south and east. In the valleys the severity of the storm was felt alike on the hills and along the streams.

On the following morning the chestnut and oak slopes showed a vast array of whitened, splintered tops and trunks where the limbs had been torn away. It was a striking, though not a pleasing, picture. It was an easy matter for one to stand in one spot and count hundreds of trees which had lost a portion or all of their tops and branches because of the weight of the accumulated ice. In the heads of some of the coves in Pisgah Forest the ice on the ground was 20 inches or more in depth where it had fallen from the trees. In numerous instances white oak, chestnut oak, and red oak with their strong fibers were broken off sheer at a height of 20 feet from the ground. One 16-inch white oak was observed in a small opening in the surrounding forest with its trunk snapped in two. No defect contributed to its fall. The number of trees in the region which plainly showed the marks of the ice storm must have totaled in the hundreds of thousands.

Apparently no one species withstood the shock of the ice better than another. This observation applies particularly to the mixture of the species where the ice deposit was the heaviest. Probably more chestnut trees were injured than any other species. This was due probably to the fact that chestnut is numerically the leading species in the region rather than to any brittle quality of its wood. Young trees with flexible branches suffered as severely as did old trees of stiffened fiber.

Oaks of all species, chestnut, basswood, yellow poplar, white pine, yellow pine, and even hickory were hard hit. Second-growth yellow poplar coming up in dense stands